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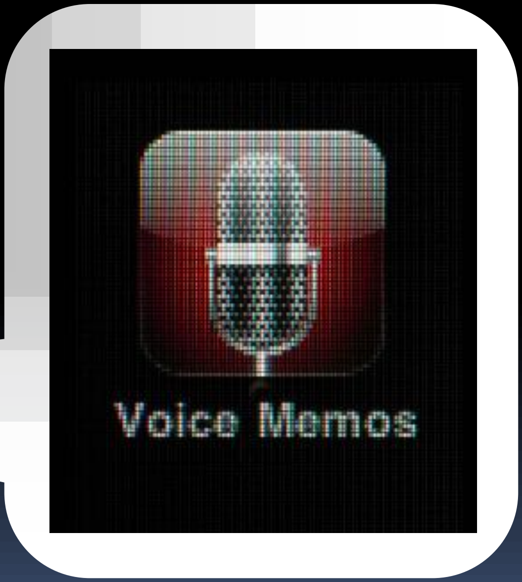
THE IPHONE AS A USEFUL AND VALID TOOL IN LARYNGOLOGY

Outline

- Background
  - iPhone
  - Acoustic measures
- Research question
- Normal voice (Cross-system validation)
- Pathological voice:
  - Methodology
  - Results
    - Normals vs. patients
    - Case presentations (pre and post-surgery)
- Conclusions

Background - iPhone

- iPhone (first released in: 2007): a multi-media enabled mobile phone with advanced
  - Computing capabilities
  - Connectivity: Internet and email access
- iPhone 3G & up: sampling rate = 48,000 Hz (Lossless)



Background – Acoustic Measures

- **Time-based measures:**
  - **Fundamental frequency (F0):** affected by mass and stiffness
    - edema (smokers): decreased F0 (Sorensen & Horii, 1982)
    - Voice patients have difficulties maintaining a constant pitch (Kotby, Titze, Saleh, & Berry, 1993).
    - Speaking F0 changes after treatment of functional voice (Roy & Taskco, 1994)
  - **Perturbation measures**
    - Jitter (or percent jitter; %Jit): cycle-to-cycle pitch variation (e.g., Eskenazi, Childers, & Hicks, 1990; Dejonckere, Remacle, Fresnel-Ebaz, Woisard, Crevier-Buchman, & Millet, 1996; Wolfe & Martin, 1997; Bhuta, Patrick, & Garnett, 2004)
    - Shimmer (or percent shimmer, %Shim): cycle-to-cycle amplitude variation (e.g., Dejonckere et al., 1996; Wolfe & Martin, 1997; Bhuta et al., 2004)
    - Signal to noise ratio (SNR): energy ratio between periodic & aperiodic components (e.g., Wolfe & Martin, 1997; Brockmann, Storck, Carding, & Drinnan, 2008)

    Less hoarse = decreased jitter & shimmer; increased SNR

Background – Acoustic Measures

- **Frequency-based measures (i.e., spectral measures):**
  - **Sentence:** Spectral tilt (ST): amplitude difference between the highest spectral peak between 0-1 kHz and that between 1-5 kHz

    Higher ST = vocal hypofunction (Löfqvist, 1987; Mendoza, Munoz, & Valencia Naranjo, 1996)
  - **Vowel:**
    - Formants One and Two frequencies (F1 and F2): Affected by vocal tract configuration (constriction or tongue placement);

      Larger vowel space area (F1-F2 plot of vowels) = greater intelligibility

      (e.g., Bradlow, Toretta, & Pisoni, 1996; Roy, Nissen, Dromey, & Sapir, 2009; Turner, Tjaden, & Weismer, 1995; Weismer, Jeng, Laures, Kent, & Kent, 2001)
    - H1-H2: amplitude difference between the first two harmonics

      Smaller H1-H2 = less breathy or thicker voice

      (e.g., Klatt & Klatt, 1990; Hillenbrand, Cleveland, & Erickson, 1994; de Krom, 1995; Hillenbrand & Houde, 1996; Stone, Cleveland, Sundberg, & Prokop, 2003)
    - Singing power ratio (SPR): amplitude difference between the highest spectral peak between 0-2 kHz and that between 2-4kHz

      Smaller SPR = greater voice projection power

      (e.g., Omori, Kacker, Carroll, Riley, & Blaugrund, 1996)

Research Question

- Are iPhone recordings adequate for acoustic assessment of speech and voice quality in
  - Normal voice
  - Pathological voice, for the purpose of:
    - Identifying voice aberrations: i.e., differentiating normal from pathological voices
    - Monitoring voice changes: e.g., detecting pre and post-treatment differences?

Normal Voice

- Poster presentation, January 12:

  Lin, E. & Hornibrook, J. “The Suitability of iPhone Recordings for the Acoustic Measures of Speech and Voice Quality.”

- Methodology:
  - Simultaneous voice recordings (sustained vowels & sentences) using an iPhone & a direct digitization system
  - 11 normal speakers (6 females & 5 males), aged 27-67 years

    (Mean = 41.8, SD = 16.7)
  - Acoustic measures:
    - Sentence-based: ST
    - Vowel (50 ms segment): F0, perturbation (%Jit, %Shim, SNR), H1-H2, SPR, F1, & F2

- Findings:
  - Relatively high cross-system correlations (r = 0.74 to 0.98), demonstrating adequate parallel validity.
  - However, mean normalized absolute inter-system differences are optimal (i.e., lower than 20%) only for F0, F1, & F2, suggesting that most quality-related acoustic measures are

    not directly comparable.

Pathological Voice

- Methodology:
  - Participants: 22 patients (10 males & 12 females;
    aged 25-92 yrs, Mean = 54.8, SD = 18.5), including 5 pre & post-surgery cases
  - Participant's task: read the first 6 sentences of "Rainbow passage"
  - Measures:
    - Subjective assessment: 2 listeners, with 3rd sentence randomly presented twice & judged on a 4-point (0-normal, 1-slight, 2-moderate, 3-severe) scale

      GRBAS (G: grade of hoarseness, R: roughness, B: breathiness, A: asthenia, S: strained)
    - Acoustic measures: same as previous study; using TF32 (Milenkovic, 2000)
      - Sentence-based measure: ST
      - Vowel-based measures (/i/, /a/): F0, %Jit, %Shim, SNR, H1-H2, SPR, F1, & F2
      - Vowel space area: F1-F2 plot of /i/, /a/, /u/
  - Analysis:
    - Group comparisons:
      - Normal vs. patient (for males & females separately)
      - Pre vs. post-surgery (for 5 patients):
        - Visual analysis: Normalized scores (z scores), calculated via a linear transformation using the means and standard deviations (SD) of the normal data in previous study, i.e.,

          z = (raw score – Mean)/SD

Measurement Reliability

- Subjective assessment: the two ratings of the same token for all data (11 normals + 22 patients + 5 post-surgery cases) were highly correlated except for roughness (good intra-judge but poor inter-judge reliability).
- Acoustic measures:
  - Automatic computer derivations of acoustic measures: 100% reliability, except for errors due to variation in vowel segmentation.
  - All data from the five pre and post-surgery cases (vowel-based measures: 5 patients X 2 visits X 2 vowels) were re-segmented and analyzed. The measure-remeasure reliabilities were found to be relatively high for all vowel-based measures:

Subjective GRBAS Ratings

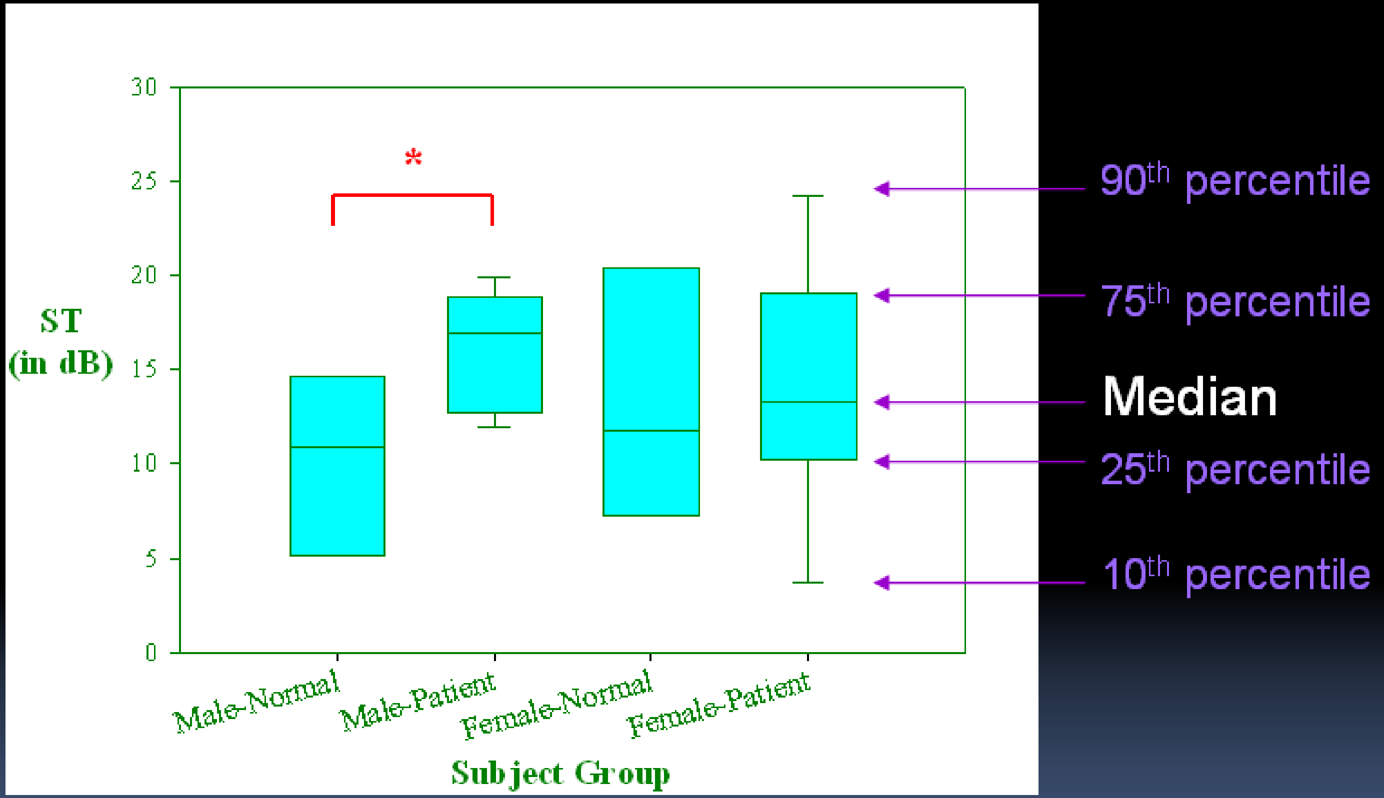
	Intra-judge			Inter-judge
	n	r1	r2	r
G	38	0.91	0.90	0.85
R	38	0.88	0.84	0.47
B	38	0.82	0.89	0.79
A	38	0.91	0.96	0.86
S	38	0.88	0.86	0.79

Acoustic Measures

	n	r
F0	20	0.99
%Jit	20	0.99
%Shim	20	0.98
SNR	20	0.97
F1	20	0.93
F2	20	0.88
H1-H2	20	0.97
SPR	20	0.96

Normals vs. Patients

- Spectral Tilt (ST): Patients > Normals



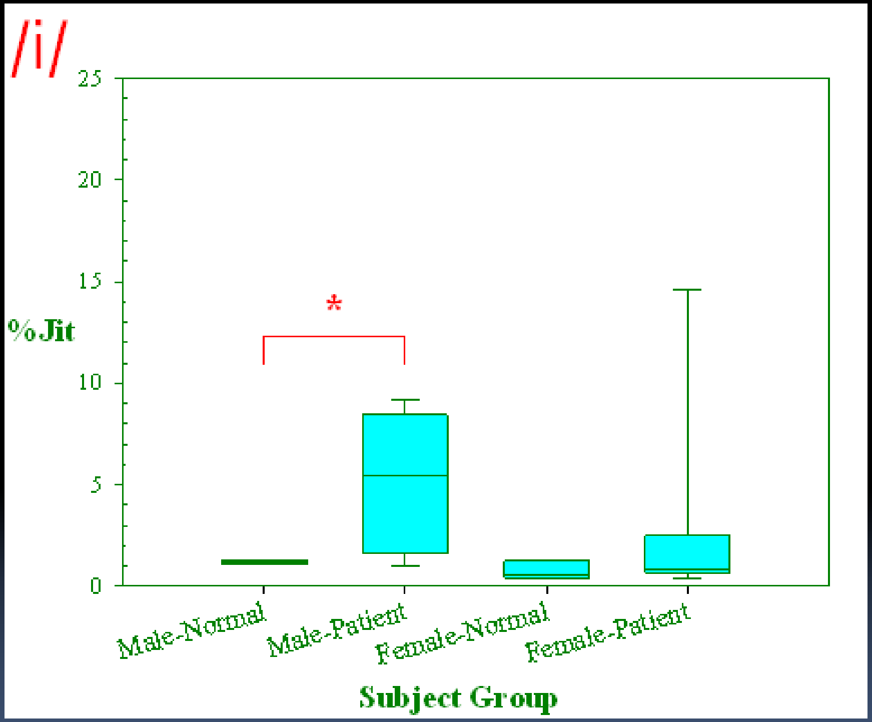
Result of Rank Sum tests:

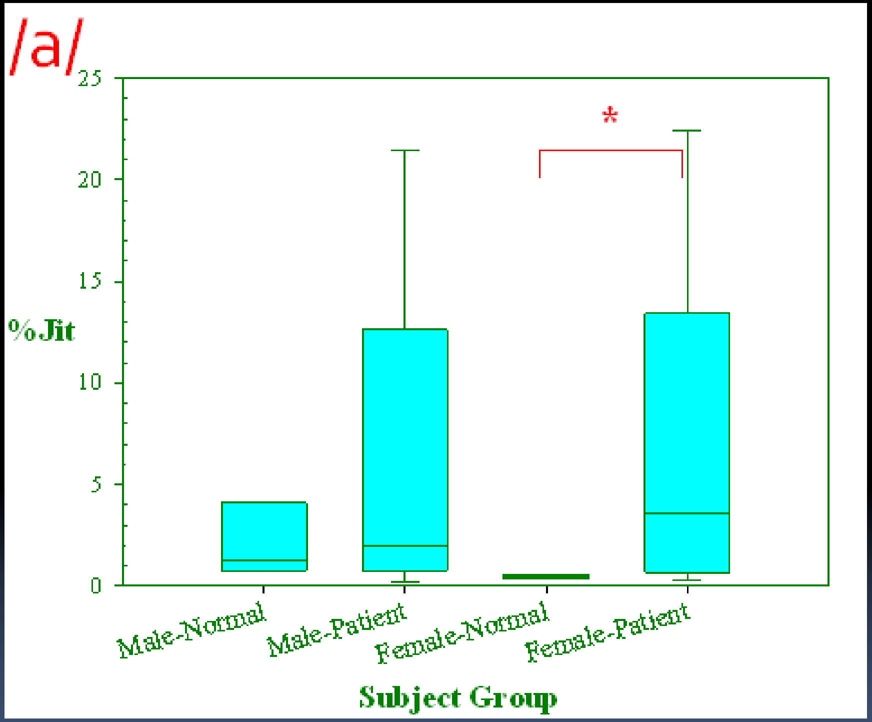
- Male: Patients (n = 10) have a significantly higher median ST than normals (n = 5).
- Female: Patients (n = 12) has a higher median ST than normals (n = 6) but the difference is not statistically significant.

* : Significant at 0.05 level

Normals vs. Patients

- %Jit: Patients > Normals

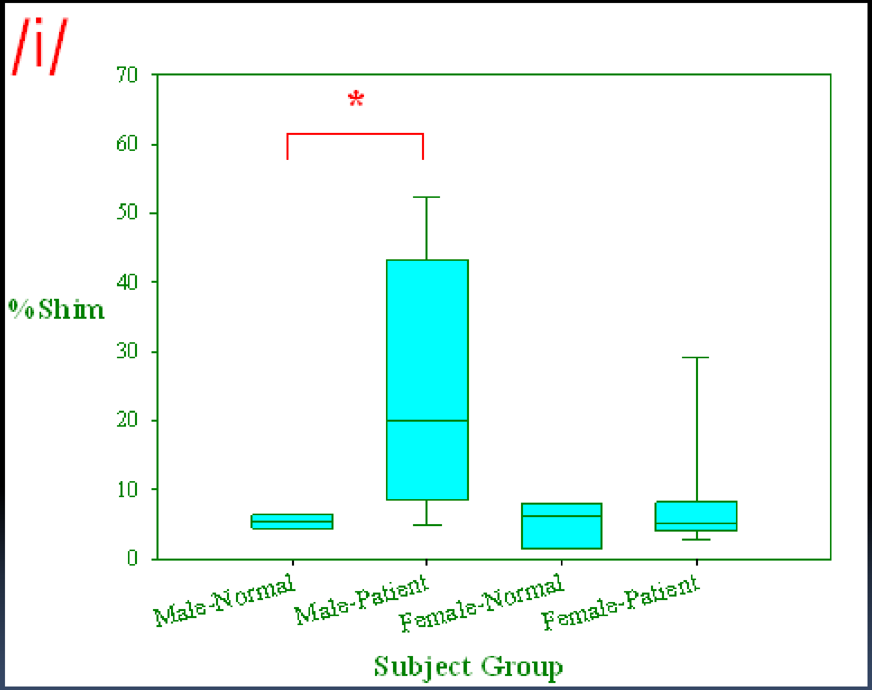


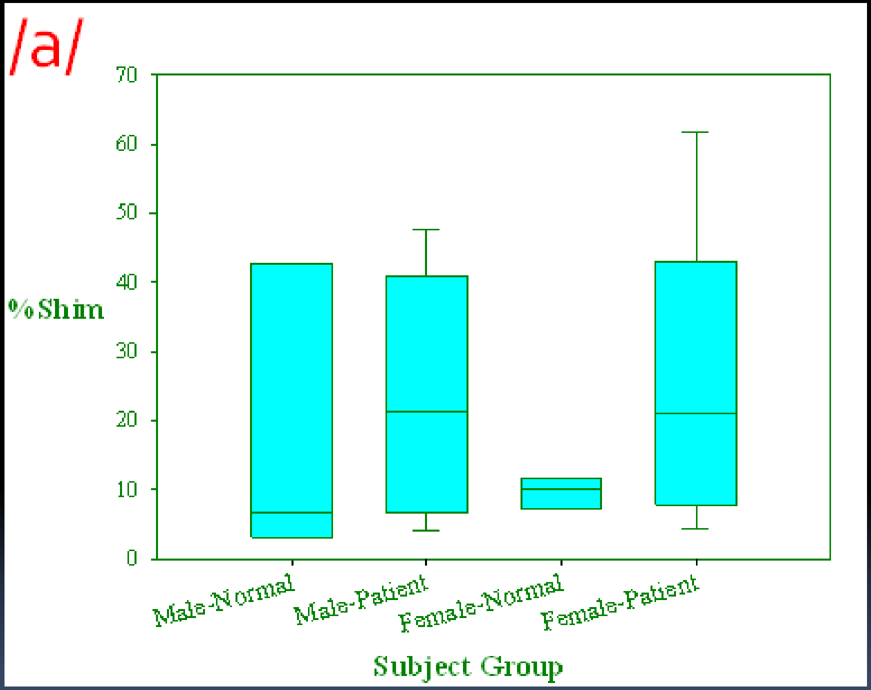


* : Significant at 0.05 level

Normals vs. Patients

- %Shim: Patients > Normals

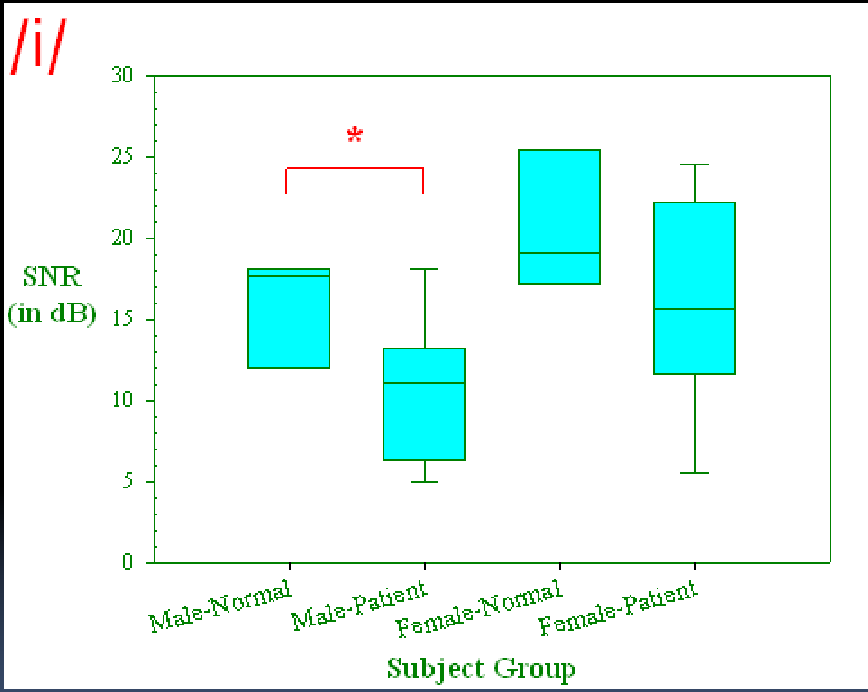


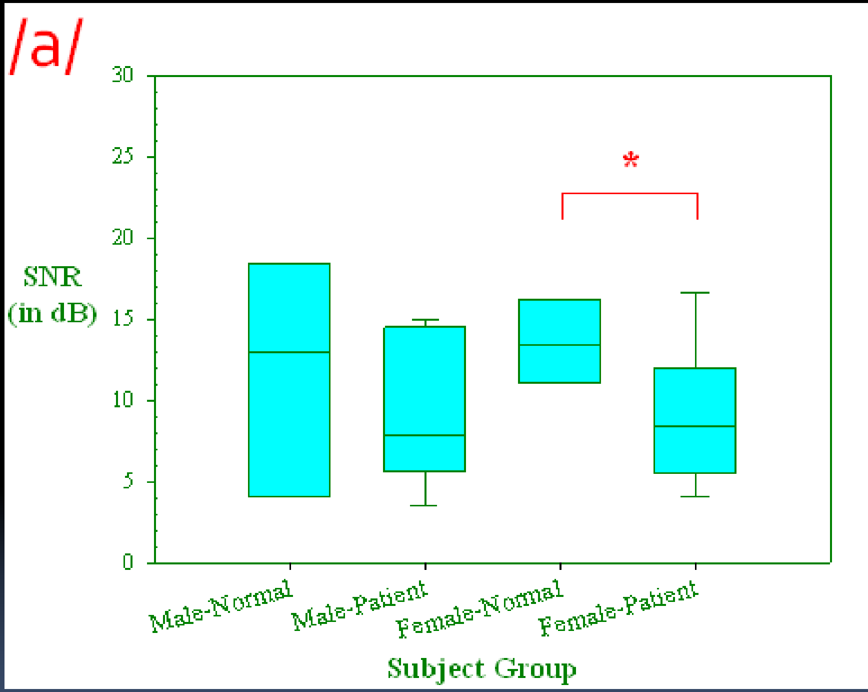


* : Significant at 0.05 level

Normals vs. Patients

- SNR: Patients < Normals

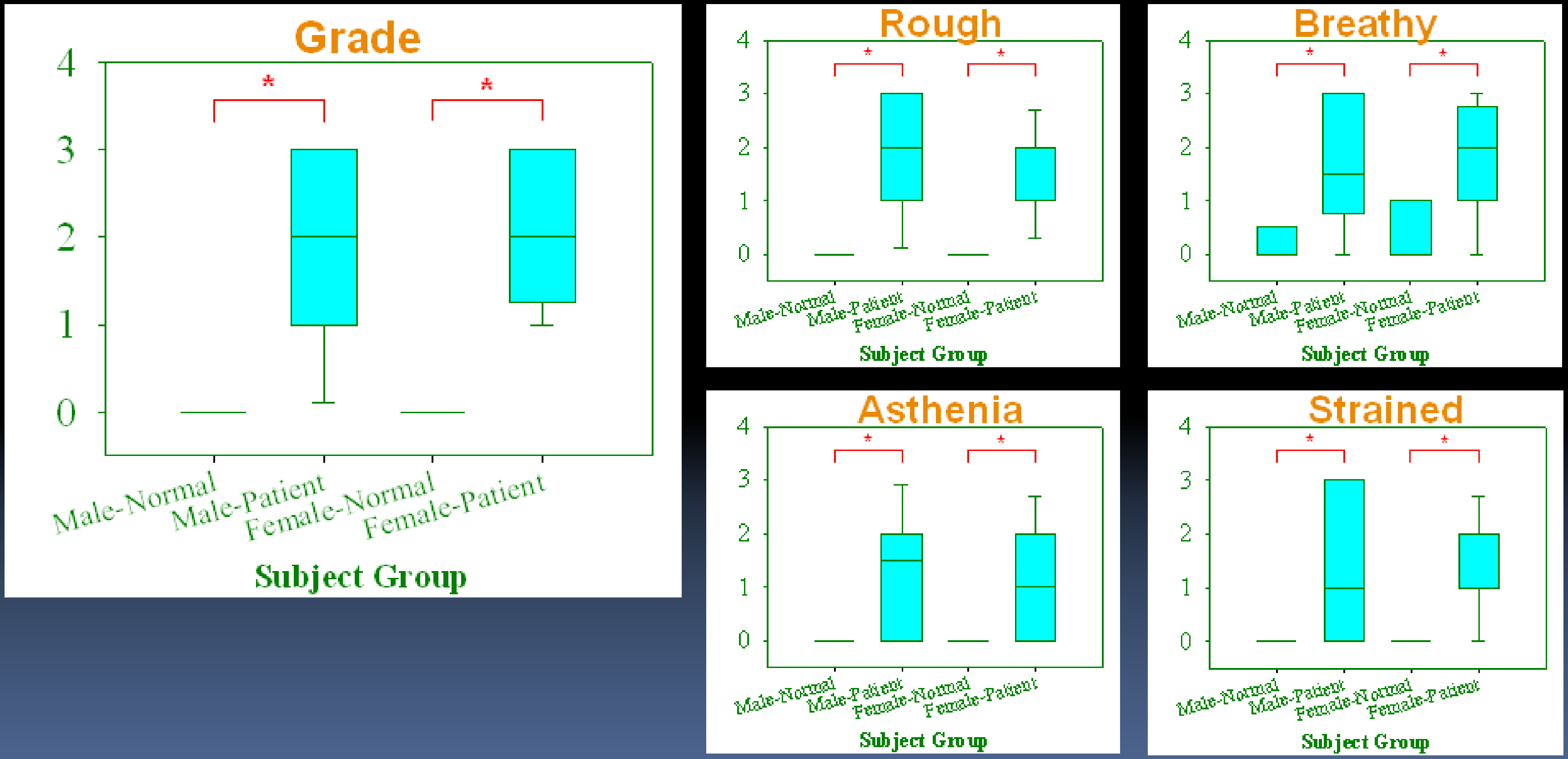




* : Significant at 0.05 level

Normals vs. Patients

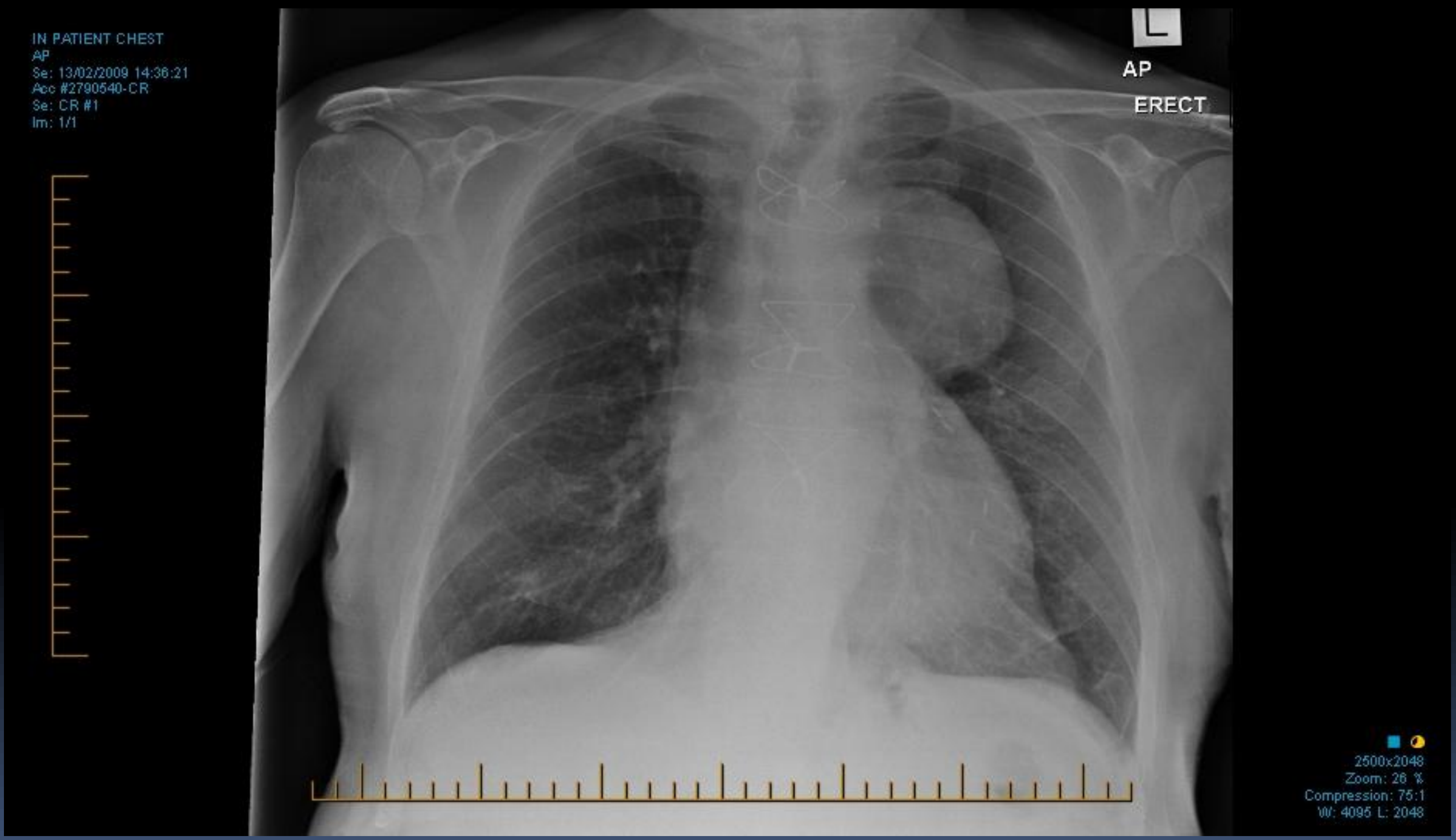
- Subjective (GRBAS): Patients > Normals



* : Significant at 0.05 level

Case One: Left Vocal Fold Paralysis

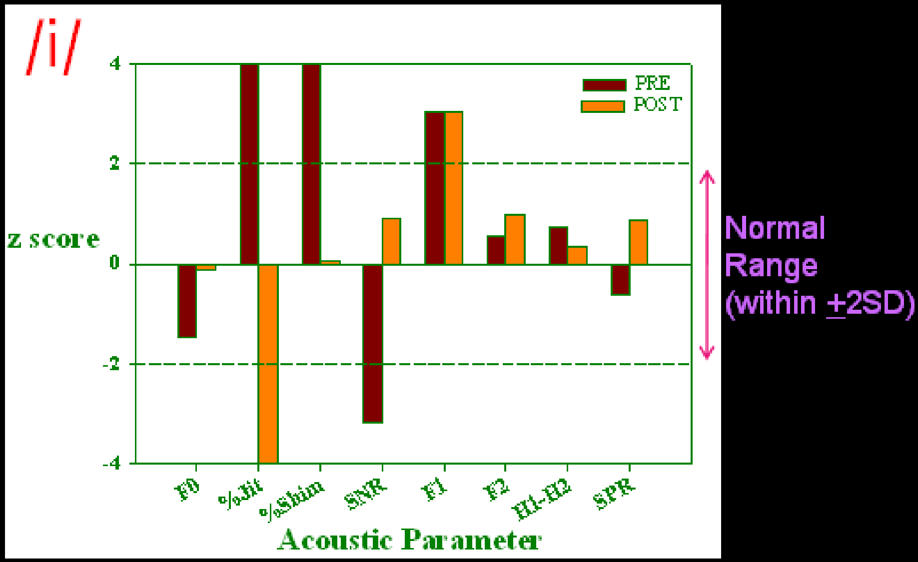
- Male, aged 79 yrs (M79), aortic arch aneurysm

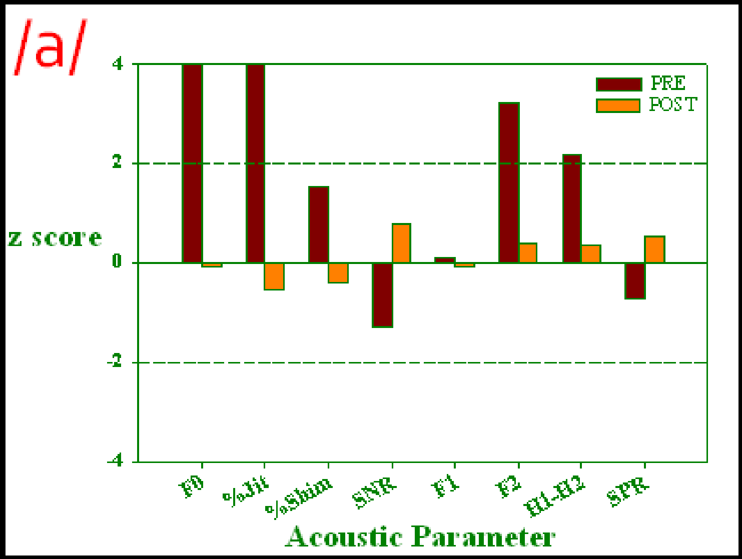


PRE

POST (medialization laryngoplasty)

Case One: M79, VF Paralysis & Medialization





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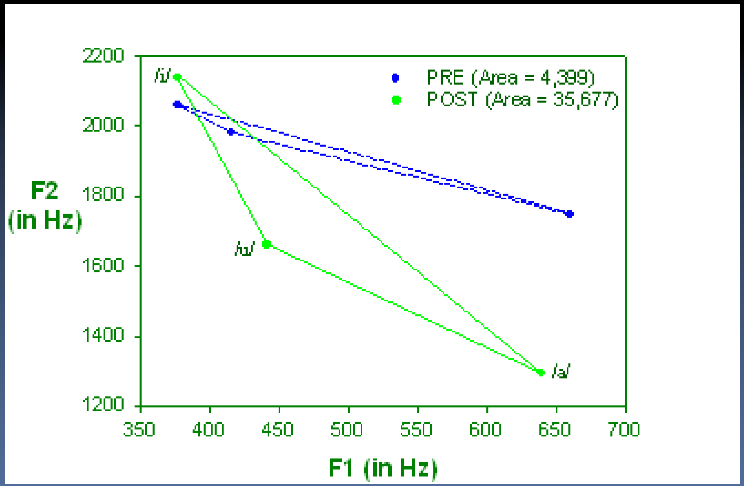
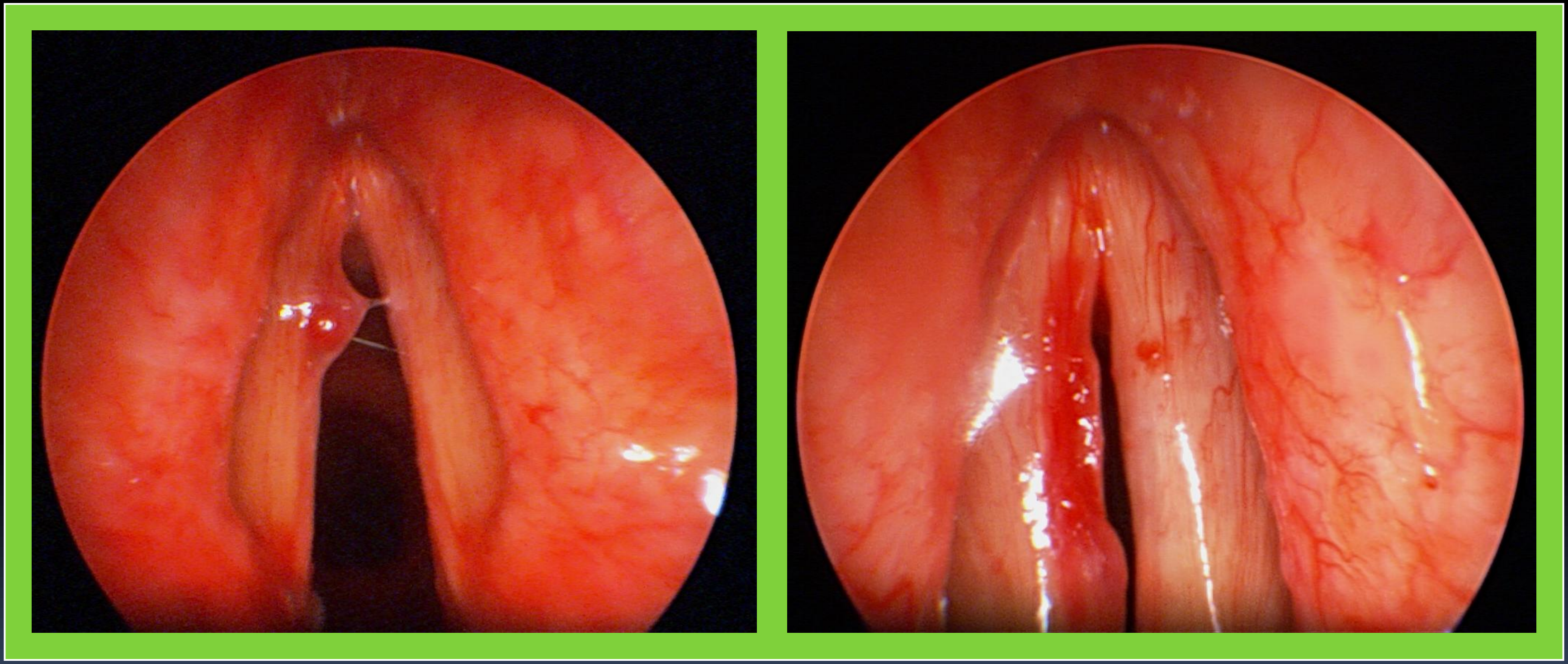


Improvement after surgery:

- lower pitch: decreased F0 (/a/)
- less hoarse:
  - decreased %Jit & %Shim
  - increased SNR
- less breathy: decreased H1-H2
- more intelligible:
  - Increased vowel space area
    - F2: increased for /i/, decreased for /a/

Case Two: Polyp on LVF

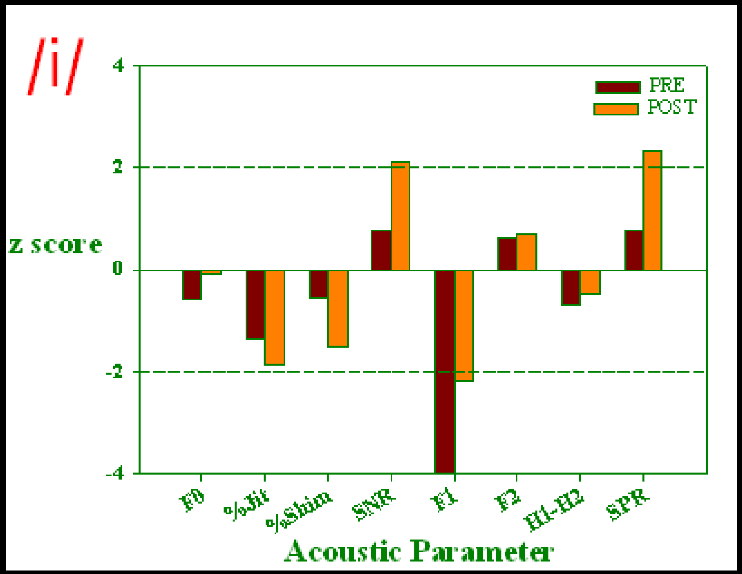
- Male, aged 33 yrs (M33)

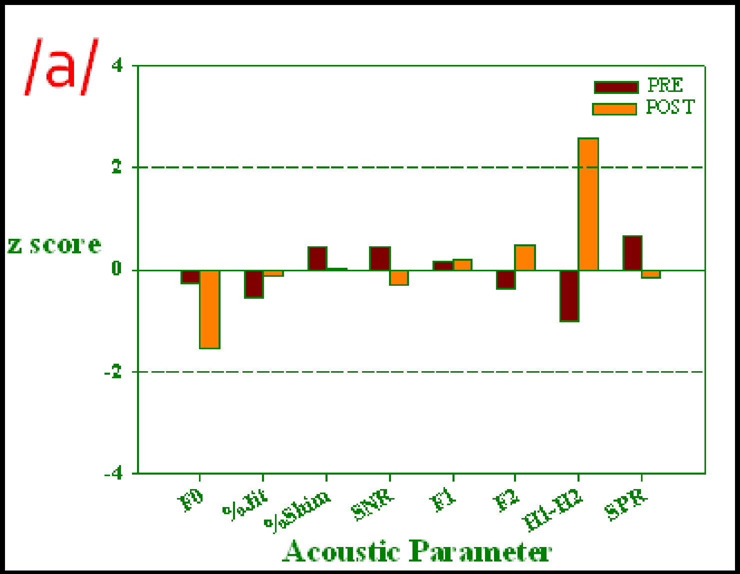


PRE

POST (microsurgery)

Case Two: M33, Polyp & Microsurgery





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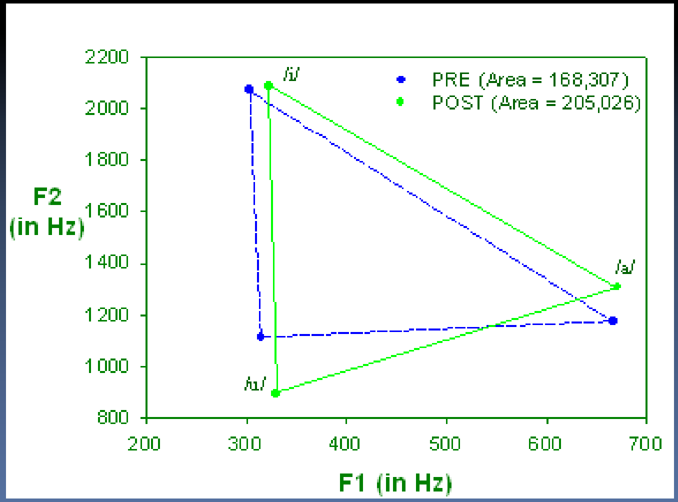
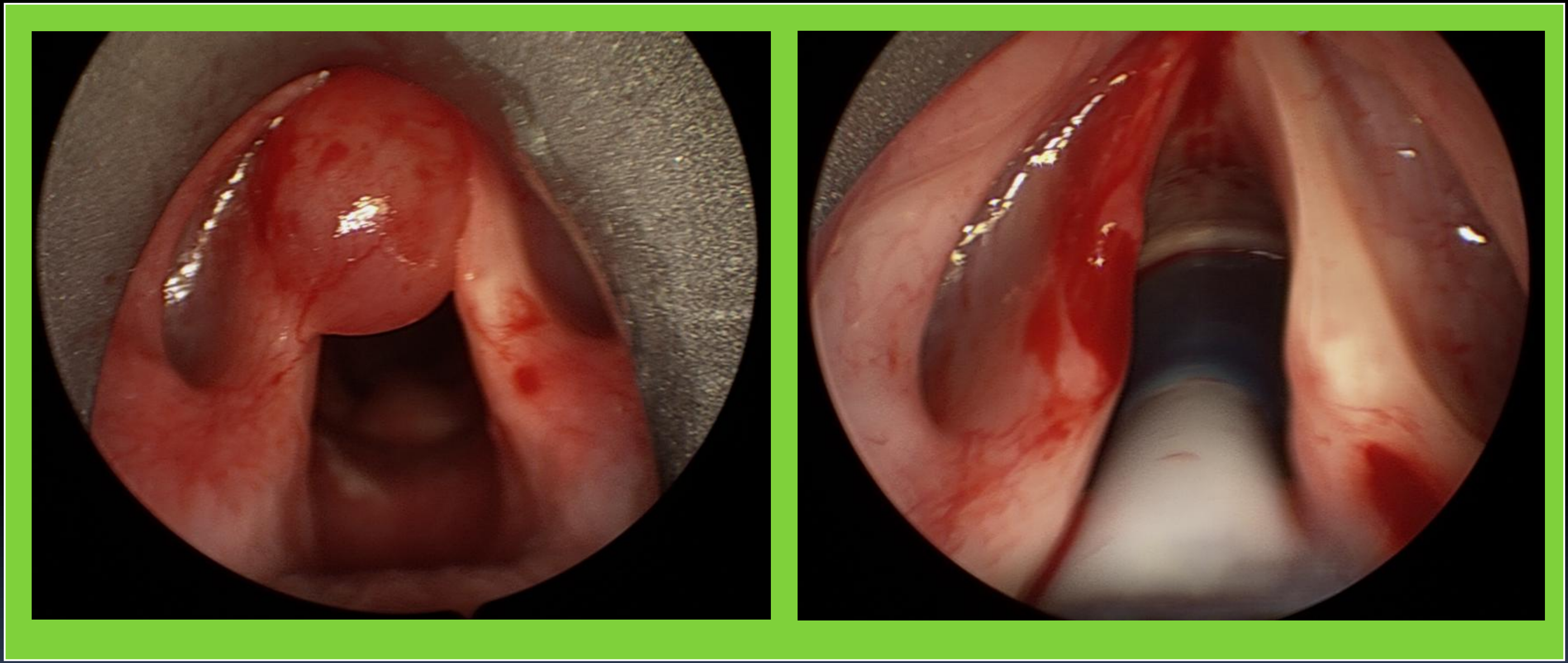


Improvement after surgery:

- less hoarse:
  - decreased %Jit (for /i/) & %Shim
  - increased SNR (for /i/)
- more breathy (or thinner voice): increased H1-H2
- more intelligible:
  - Increased vowel space area
    - F1: increased for /i/ & /a/
    - F2: increased for /i/ & /a/

Case Three: Inflammatory myoblastic tumor

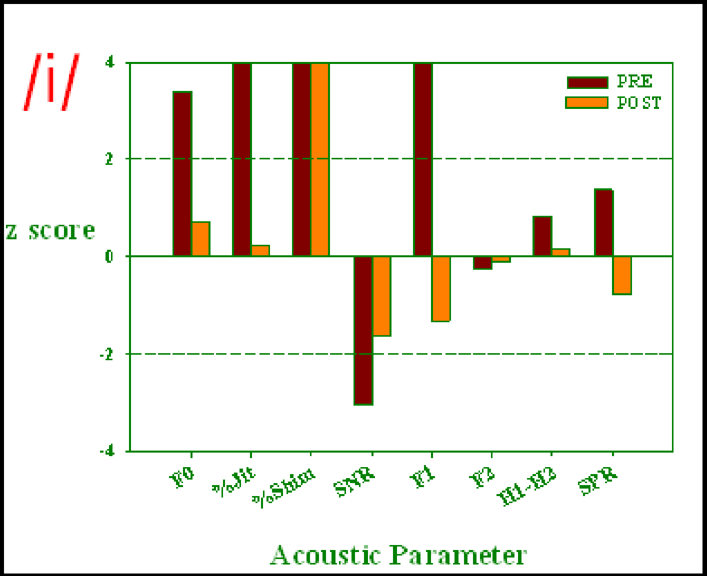
- Male, aged 34 yrs

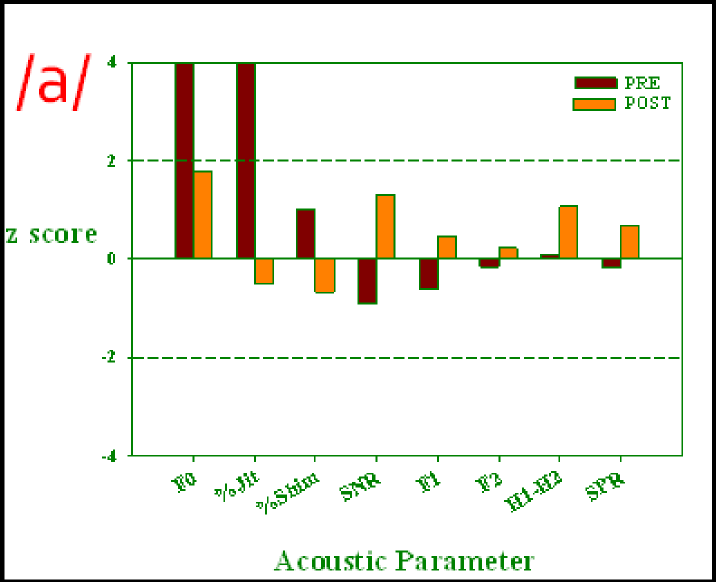


PRE

POST (microsurgery)

Case Three: M34, IM tumor & Microsurgery





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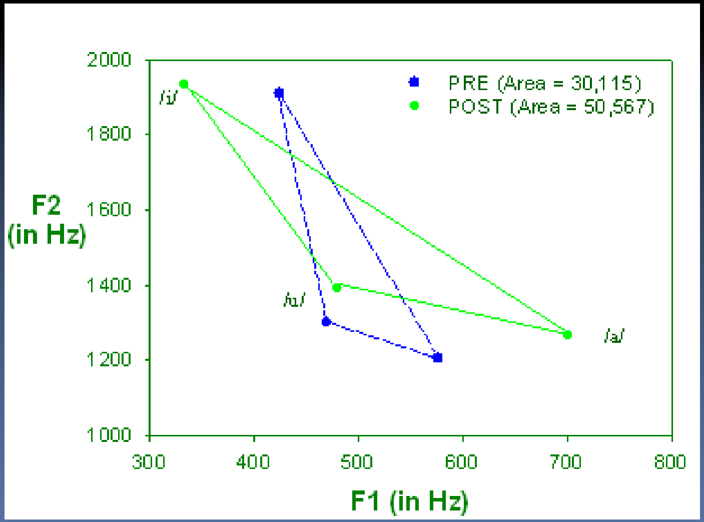
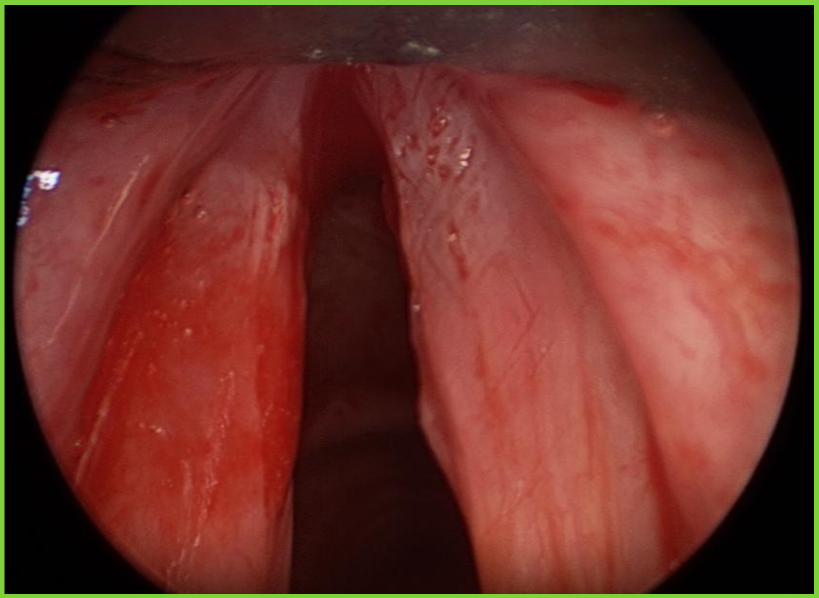


Improvement after surgery:

- lower pitch: decreased F0
- less hoarse:
  - decreased %Jit & %Shim
  - increased SNR
- more intelligible:
  - Increased vowel space area
    - F1: decreased for /i/, increased for /a/
    - F2: increased for /i/ & /a/

Case Four: Mass lesion on RVF

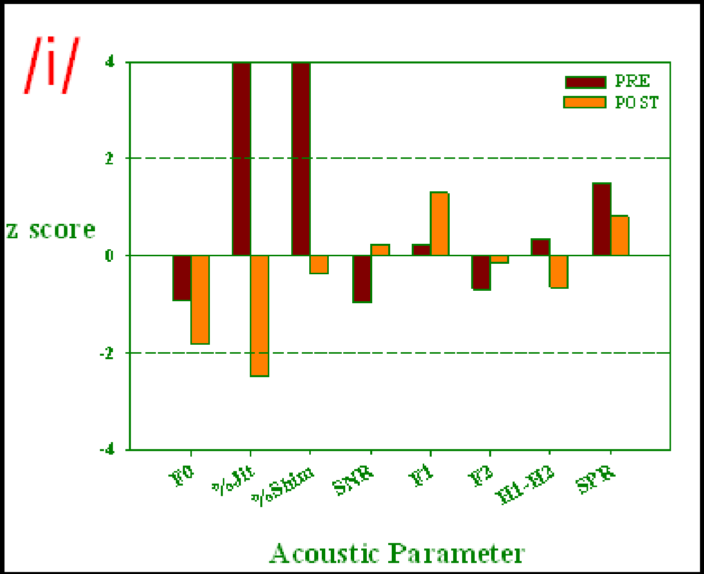
- Male, aged 46 yrs



PRE

POST (microsurgery)

Case Four: M46, Lesion & Microsurgery



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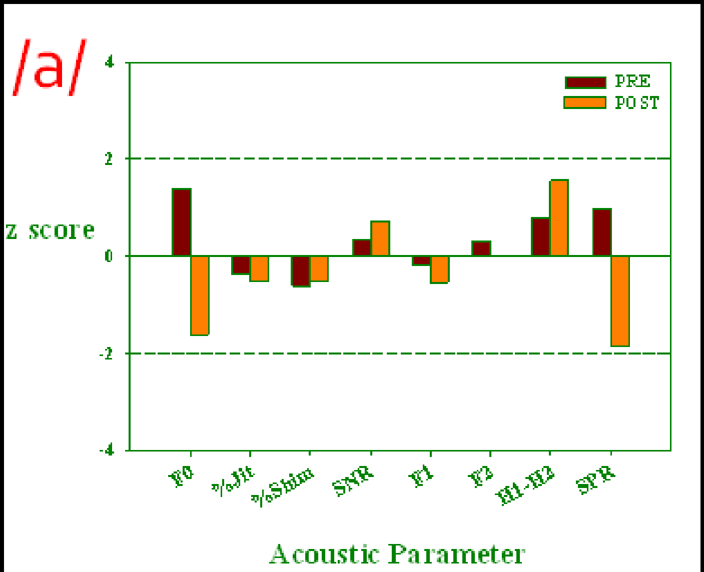

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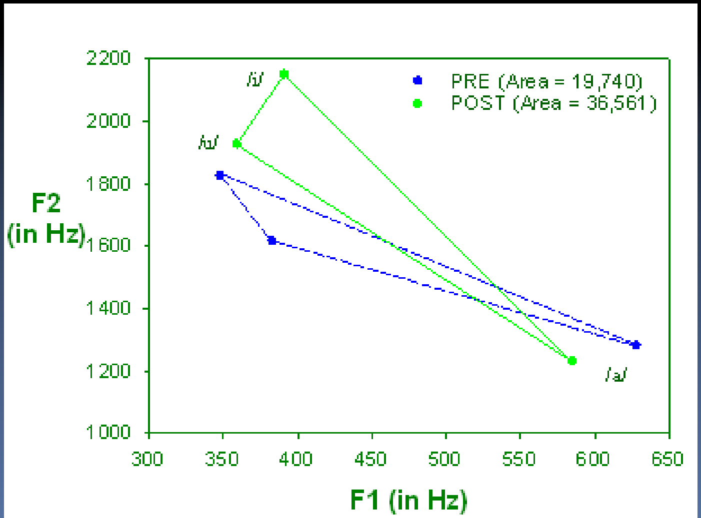
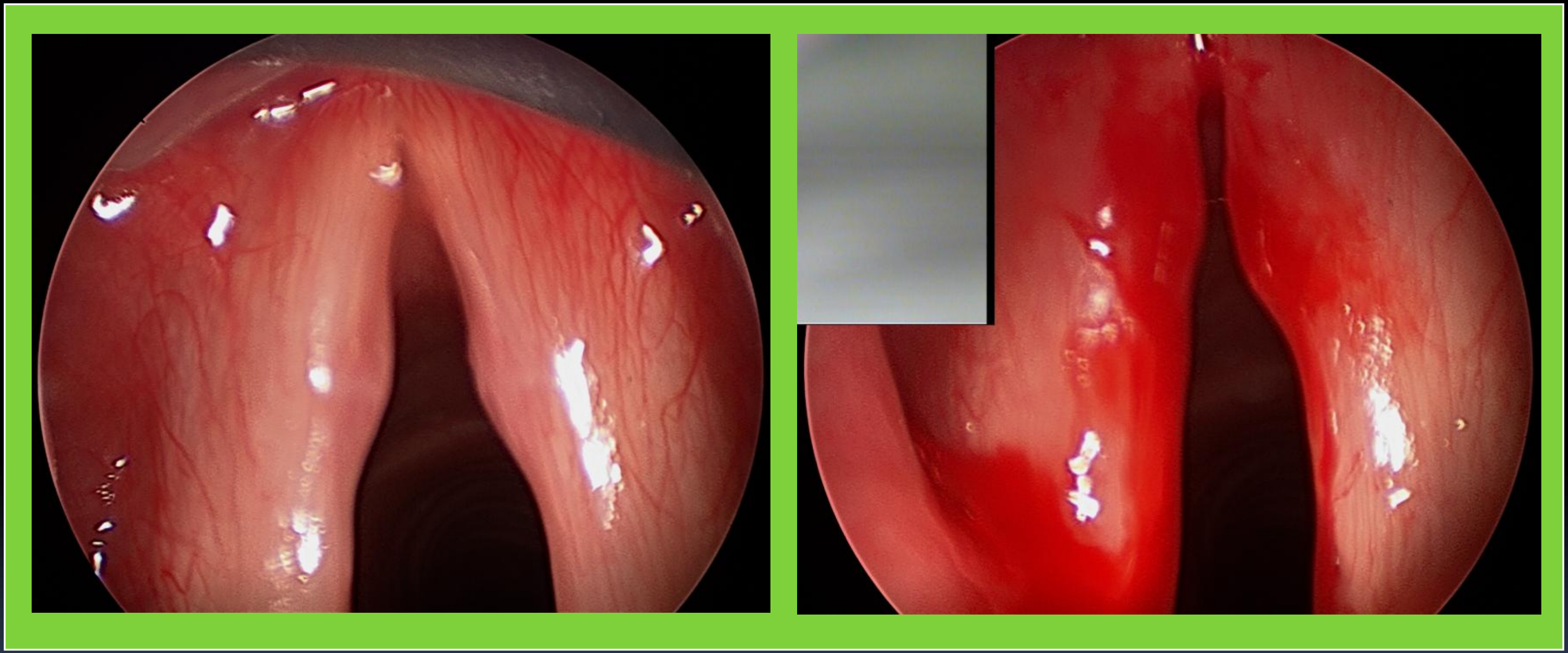


Improvement after surgery:
- lower pitch: decreased F0
- less hoarse:
  - decreased %Jit & %Shim for /i/
  - increased SNR
- more intelligible:
  - Increased vowel space area
    - F2: increased for /i/, decreased for /a/

Case Five: Nodules

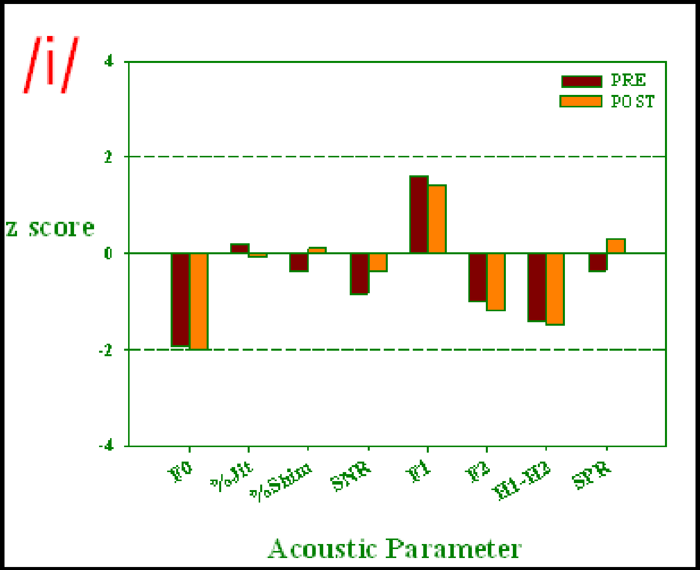
- Female, aged 39 yrs

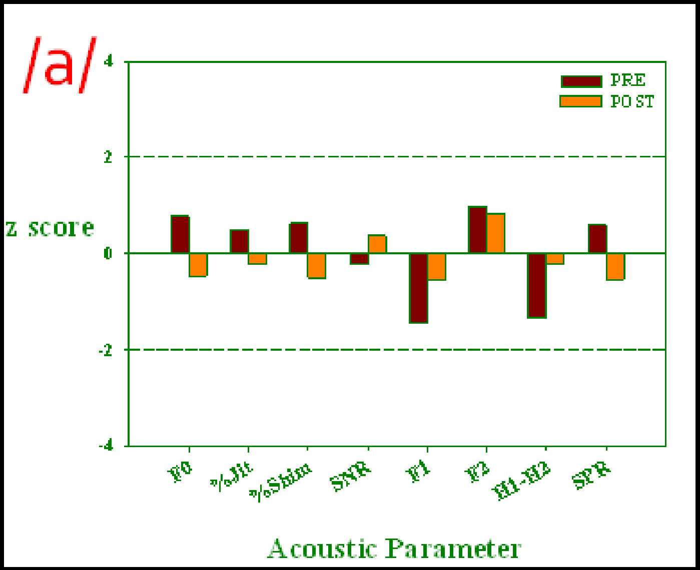


PRE

POST (microsurgery)

Case Five: F39, Nodules & Microsurgery





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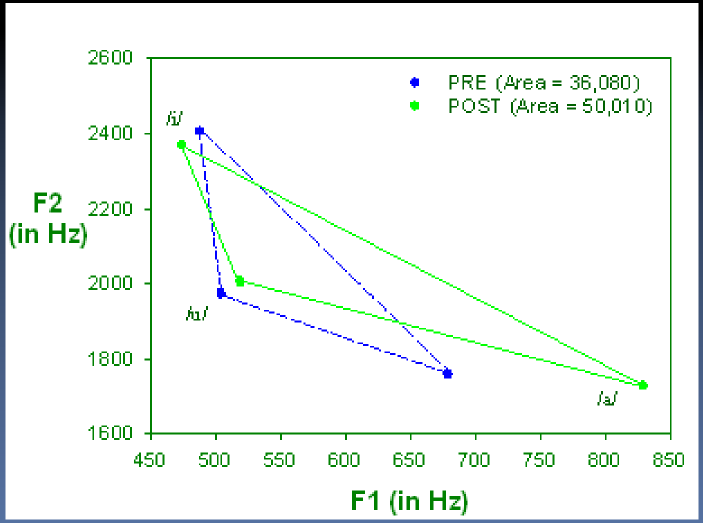
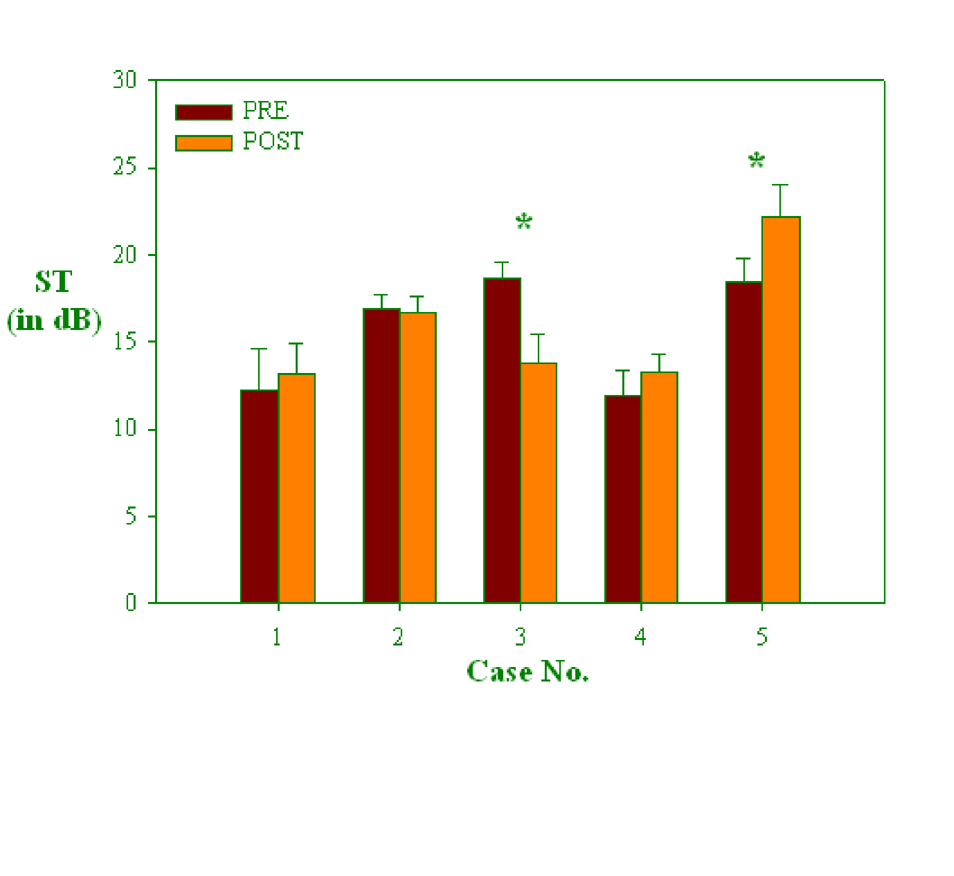


Improvement after surgery:

- lower pitch: decreased F0
- less hoarse:
  - decreased %Jit & %Shim
  - increased SNR
- less breathy: decreased H1-H2
- more intelligible:
  - F1: decreased for /i/, increased for /a/

Spectral Tilt: Pre vs. Post

- Case 3 (M34, IM tumor): ST decreased after treatment (i.e., less hypofunction)
- Case 5 (F39, nodule): ST increased after treatment



Summary of Main Findings

- Relatively high measure-remeasure and acceptable between-system reliabilities for all acoustic measures included in this study
- Most measures are adequate for detecting voice improvement, especially:
  - Perturbation measures (%Jit, %Shim, SNR) & vowel space area consistently demonstrate positive changes after treatment
- Frequency-based measures are more variable:
  - H1-H2 may reflect subtle changes in breathiness (or voice thickness)
  - Changes in SPR may be vowel-dependent
  - Changes in ST may be gender or pathology-dependent

Conclusions

- Voice recordings using iPhone are adequate for acoustic measurement of speech and voice quality
- However, due to large inter-subject variations, most of these measures are more useful for intra-subject comparison (to monitor changes within individuals) than for norm-referenced comparison

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